# The Elastic Impact of Polishing Pad for Sapphire Polishing

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***Abstract*- Sapphire substrate's application such as LED, cover glass will be expanded year by year. After lapping, polishing is needed to get smooth surface. In recent years, high throughput at polishing became to be required for expansion of demand. Polishing pads were classified to fiber type, urethane and suede one. Fiber type made from polyurethane, polyether fiber has been used and it performed moderate removal rate from contact area caused by fiber. On the other hand, polishing conditions such as down force, shear one became to be heavier recently to increase removal rate. In case of utilizing that environment by designing with dynamic pad's feature, the pad should reveal higher removal rate. This study sought a new key factor which can achieve high removal rate under the environment. Firstly pad's elastic feature was focused by using nylon fiber for new design and it was confirmed that there was correlation between the content and removal rate was. Then it was found out that Young's modulus was the key factor and it seemed to increase contact area at dynamic environment. Finally, urethane type designed on low Young's modulus was evaluated. As result, it was found out that this approach was efficient both for fiber type and urethane one to achieve high removal rate.***

## I. INTRODUCTION

Sapphire has been used for LED and for cover glass. The application for lighting, mobile phone will be expanded year by year. The substrate sliced after ingot growth was lapped. After lapping, it has certain roughness and damage layer. After that, polishing was needed to remove them for luminescence, mechanical strength. Then polishing pad and slurry were used and high throughput was required[1]. Basically, it was important for polishing pad to have much contact area to achieve high removal rate[2] [3].

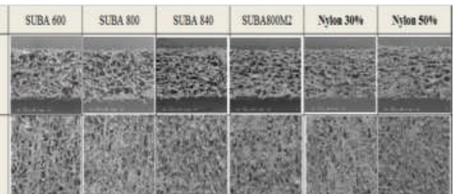
Regarding polishing pads, there are some types such as fiber type, urethane and suede. Fiber type has been used as typical pad for sapphire polishing and it was made from polyether fiber, polyurethane. It performed moderate removal rate the due to certain contact area by fiber. On the other hands, polishing conditions such as down force, shear force were changed to heavier recently to get higher removal rate. Therefore, pad's modification utilized those environments seems to be more effective pad's approach. Then elastic feature of polishing pad seemed concern to removal rate by changing contact area.

This study seeks to verify how the new pad's feature influences to removal rate. First based on fiber type with elastic fiber, fundamental test was completed to achieve higher removal rate than one with typical fiber. Then it was confirmed that Young modulus was a new important factor. Furthermore, it was also confirmed whether urethane type designed with low Young's modulus polymer could get higher pad.

## II. EXPERIMENTAL

It is known that nylon fiber has elastic feature. Two fiber types which include some nylon fiber and some polyether one and were impregnated with same poly urethane as SUBA$^{TM}$ 600, were evaluated at the initial test. In addition, some pads formulated from different hardness polyurethane and only polyether fiber were prepared to compare with these pads as shown in Table1.

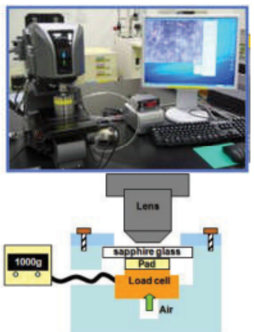
TABLE 1
Comparison of properties between with fiber and conventional

| | SUBA 600 | SUBA 800 | SUBA 840 | SUBA800M2 | Nylon 30% | Nylon 50% |
|---|---|---|---|---|---|---|
| Cross Section (x50) |  | | | | | |
| Surface (x 50) | | | | | | |
| Thickness | 1.28 mm | 1.28 mm | 1.27 mm | 1.25 mm | 1.27 mm | 1.27 mm |
| Hardness | 80 | 82 | 85 | 87 | 85 | 86 |
| Compressibility | 3.8% | 3.6% | 2.9% | 2.4% | 3.0% | 3.3% |
| Recovery | 73% | 72% | 70% | 72% | 69% | 70% |
| AVE. Roughness | 13 um | 13 um | 13 um | 13 um | 13um | 13um |
| Density | 0.37 g/cm3 | 0.41 g/cm3 | 0.39 g/cm3 | 0.45 g/cm3 | 0.37g/cm3 | 0.37g/cm3 |

Young's modulus was mentioned as example of elastic feature and it means elongation parameter in elastic deformation. At this test, the modulus was focused, because it would correlate to polishing shear force and seemed to bring about change of contact area. It was measured with peel tester (AUTOGRAPH SHIMAZU, AG-1kNIS) and each pad piece cut to constant size was elongated with 300mm/min by 110% length. The initial length was 100mm and the modulus was calculated from the elongation force and the cross section. As reference data, contact area was measured as shown in Table2.

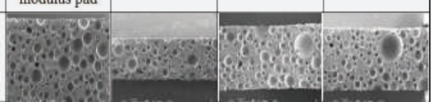
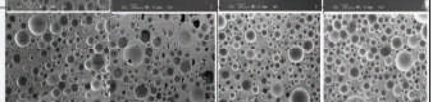
c-plane substrate were used for polishing. Removal rate was measured from pre-polishing substrate weight and post-polishing one. The polishing test were conducted using Nitta Haas slurry MS2025, which is formulated from colloidal silica and KINIK diamond disk conditioner on single side polisher with 20” platen. The polishing condition was 500 gf/cm$^2$ polish down force and 130/140 rpm head/platen rotation speed with 300 ml/min slurry flow rate and the time for every polishing run was 30min. Pad surface temperature and friction were monitored during polishing. At the 2nd test, it is possible for urethane pad to be modified to lower Young modulus by applying new polyurethane formulation. Pad’s properties were compared with conventional pad as shown in Table3.

TABLE 2
Measurement conditions of pad’s contact area




| | |
|---|---|
| Tester | Contact area tester (G&P) |
| Contact size | dia. 20mm |
| Down force | 500gf/cm2 |

TABLE 3
Comparison of pad properties in each urethane type

| | Low Young's modulus pad | Pad A | Pad B | Pad C |
|---|---|---|---|---|
| Cross section (x50) |  | | | |
| Surface(x50) |  | | | |
| Thickness | 2.00 mm | 0.80 mm | 1.30 mm | 1.30 mm |
| Hardness JIS-A | 88 | 81 | 84 | 84 |
| Density | 0.60g/cm3 | 0.52g/cm3 | 0.52g/cm3 | 0.52g/cm3 |

## III. Result and Discussion

### *A. Result of initial test*

Fig. 1 shows removal rate of each fiber type pad. Two pads including nylon fiber exhibited higher removal rate than another one. Actually as compared with SUBA800, SUBA600K3 doing 30% nylon had about 40% higher removal rate. In addition, the content of nylon fiber seemed to contribute the increase of removal rate.

Fig. 2 shows correlation between contact area and removal pad for each pad. As the result, some pads such as SUB600, SUBA800 and SUBA800M2 etc., indicated the strong correlation but two pads including nylon fiber did not. This means that there would be another factor concerned to removal rate. Next the correlation between Young’s modulus for each pad was shown in Fig.3. The modulus trended the increase of removal rate.

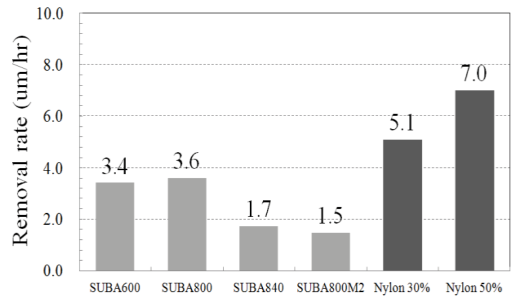



Fig. 1. Comparison of removal rate in pads with/without nylon fiber

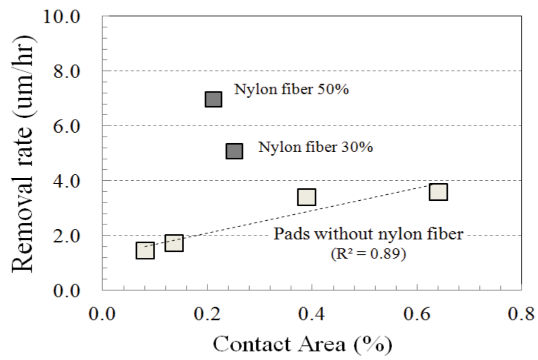



Fig. 2 Influence of contact areas to removal rate

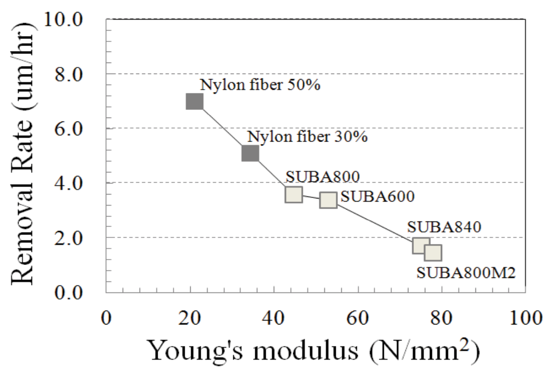



Fig.3 Correlation between Young’s modulus and removal rate ($R^2$=0.97)

Moreover, Fig.4 shows friction and pad surface temperature during polishing. Nylon has hydrophilic feature basically and there were some possibility that it increased slurry supplying to pad surface. In case of occurring the phenomenon, pads with nylon should demonstrate lower surface temperature than another pads. Whereas, SUBA600K3 and SUBA600K5 revealed higher temperature. Beside, although two pads had less contact area, these frictions were higher than another pad. Therefore, it was thought that the hydrophilic feature did not function and Young's modulus seemed to perform by increase contact area. From these result, Young's modulus was verified to correlate to removal rate for sapphire polishing.

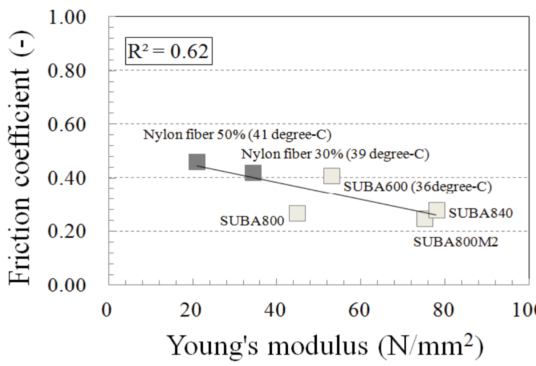



Fig.4 Friction coefficient for each Young's modulus

*B. Result of urethane type with low Young modulus*

Fig. 5 shows removal rate for each urethane pad. As the result, low Young's modulus pad exhibited higher removal rate than another urethane pads and there was the similar correlation with fiber type between Young's modulus and removal rate. As compared at the same modulus, fiber type showed slightly higher removal rate than urethane pad. This means difference of pad structure also might perform to removal rate as slurry holding in pad.

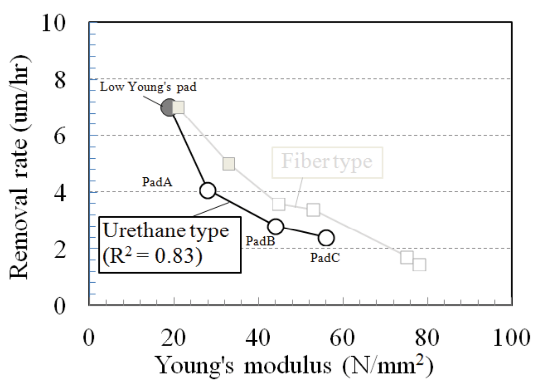



Fig. 5 Correlation between Young's modulus of Urethane pad and removal rate

*C. Discussion from polishing result*

Difference of removal rate in each pad was explained by using the following model. Fig.6 shows initial pad's surface and the surface under down force. With regards to measurement of contact area, pad has same surface as this image. Fig.7 shows pad's surface image during polishing in case of using pad which has high Young's modulus. Fig.8 indicates the image for using pad which has the low modulus.

Regarding high young modulus seemed to sustain the similar surface during polishing. Actually it was confirmed that removal rate depend on contact area in some SUBA pads. This means that those pad had resistant to changing contact for polishing shear force.

On the opposite side, it was guessed that contact area of low Young's modulus pad would increase from horizontal deformation by polishing shear so that it was guessed that more slurry abrasives possibly were moved at marginal contact area effectively by the increase. In case of using nylon fiber, measured contact areas was less than another pad but polishing friction was higher. This phenomenon seems to mean to generate the increase.

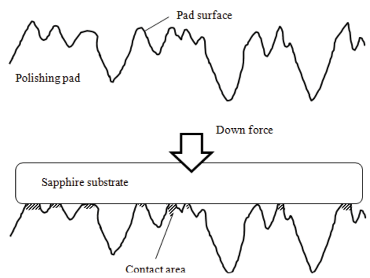



Fig. 6. (Top) Cross section Image of initial pad's surface without down force. (Bottom) The image of the surface under down force

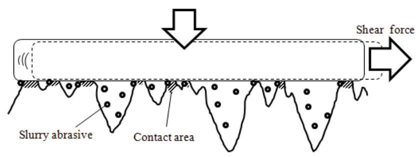



Fig. 7 The image of conventional pad during polishing

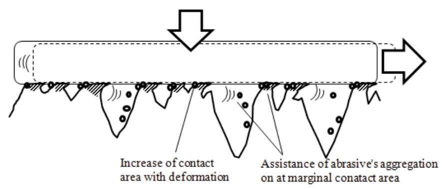



Fig. 8 The image of low Young's modulus pad during polishing

IV. SUMMARY

This study evaluated elastic feature of polishing pad from the point of view of Young's modulus to achieve high removal rate.

Comparison of removal rate for each Young's modulus was tested both for fiber and for urethane type. Low Young's modulus served as increasing removal rate. This approach is more effective than previous one such as hardness modification. In addition, urethane type with the low modulus could also achieve higher rate. Urethane type will be more expedient pad at heavier conditions than fiber type, because the risk for glazing might be lower from non continuous internal structure. In this report, it could be confirmed that the future approach based on it was effective.

## REFERENCES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